

USE OF COLLOIDAL PRECIPITATED CALCIUM CARBONATE AS A ^{Filler} FILTER IN THE PREPARATION OF PAPER

FIELD OF THE INVENTION

- 5 The invention relates to use of colloidal PCC (precipitated calcium carbonate) as a filler in the preparation of paper for the purpose of controlling the porosity and printing properties of the paper.

BACKGROUND OF THE INVENTION

10

In the connection with the manufacture of paper it is very important to be able to control the porosity of the paper. For example, a paper with low porosity is required in order to obtain an acceptable result in, e.g., ink-jet and rotogravure printing. If the paper is too porous it will function like blotting paper during printing and the resulting
15 print may appear blurred, the contrast between printed and unprinted areas or between differently coloured areas not being rendered sharply. Similarly, on a paper which is of non-uniform porosity it can be seen that the intensity of colouration varies ("mottling"), which is of course undesirable since the coloured surface appears variegated or mottled. On the other hand, the porosity of the paper can also be too
20 low, since a very dense paper will have difficulty in absorbing printing ink, which among other things may result in smudging ("set off") between printed sheets. This phenomenon can influence the printing results, the printing speed and the printing process employed in a negative manner.

- 25 The paper industry presently uses several different ways of regulating the porosity of paper. Use is made among other things of the fact that certain minerals in the form of flakes, e.g. talc and kaolin, will, as result of their form, be able to reduce the porosity since the individual particles will become deposited like the scales on a fish and thereby seal the surface. Fine silicates can be used in connection with pigmentation to
30 reduce the porosity of the paper. When they come into or onto the paper, these fine particles will close the pores which contribute to the porosity of the paper.

In order to regulate the properties of the paper, a combination of one or more fillers and a variety of other additives is often used. Among the group of additives are

alkylketene dimers (AKD), alkenylsuccinic acid anhydride (ASA), starch and retention agents. Retention agents are added to facilitate the manufacture of the paper, whilst AKD, ASA and starch are added to ensure the quality of the paper (strength, printing properties, etc.).

5

Regardless of which of the presently known methods is used, they all have drawbacks. Kaolin and talc in the form of flakes will negatively influence the brightness of the paper compared to the whiter fillers, such as ground marble or PCC (precipitated calcium carbonate).

10

The fine silicate products used for pigmentation have relatively good technical properties. However, the silicate products have the disadvantage of being much more expensive than the fillers normally used in paper manufacture. The same applies to other additives normally used in connection with paper manufacture. These are often
15 many times more expensive than a calcium carbonate filler.

Over the years, numerous attempts have been made to optimise paper compositions precisely for the purpose of improving the porosity and printing properties of the paper. The problem has been, however, that none of these approaches to a solution
20 have been ideal, since they have either had a negative influence on the other properties of the paper (among other things the brightness) or are relatively expensive to use (silicate products).

The use of colloidal PCC as such in paper is known. For example, US 4,892,590
25 discloses the use of a two-component binder system as a retention agent for paper manufacture, wherein the binder comprises colloidal PCC with a high specific surface area together with a cationic starch. The PCC used has a surface area of 10-200 m²/g, and the weight ratio between PCC and cationic starch is from 2:1 to 1:20.

30 US 4,460,637 discloses ink-jet paper (coated paper) with 2 different peaks of pore size distribution in the ink-receiving layer or layers. The desired pore size distribution can be achieved, inter alia by means of agglomerates with an average diameter of 1-50 µm in which the individual particles in the agglomerates have a size of at most

0.20 μm , e.g. colloidal particles of at most 0.01 μm ; such colloidal particles can be colloidal calcium carbonate.

It is not believed that colloidal PCC has previously been described or used as a filler in
5 paper for the purpose of controlling the porosity and printing properties of the paper.

DESCRIPTION OF THE INVENTION

It has now been found that use of colloidal PCC with a large surface area as a filler
10 makes it possible to replace a proportion of the previously mentioned pigments whilst also providing the possibility of regulating the porosity and printability properties of the paper. Compared with the previously described methods, the use of colloidal PCC has numerous advantages. It is cheap, produces low wear, it can produce greater brightness than kaolin and talc flakes, and the product is more adaptable to individual
15 types of paper.

In its broadest aspect, the present invention relates to the use of colloidal PCC as a filler to control the porosity and printing properties of paper, in particular to reduce the porosity relative to the porosity which can otherwise be achieved with other types of
20 fillers and pigments conventionally used in the manufacture of paper.

One aspect of the invention thus relates to a process for regulating the porosity and printing properties of paper, wherein a sufficient quantity of colloidal PCC having a BET surface area of 10-100 m^2/g is used as a filler to achieve a desired porosity of the
25 paper.

In another aspect, the invention relates to paper containing colloidal PCC as a filler.

In a third aspect, the invention relates to a pigment mixture which is suitable for
30 manufacture of paper and which contains colloidal PCC.

Other aspects and preferred embodiments will be apparent from the following detailed description of the invention.

As employed in the present description and claims, the term "colloidal PCC" (chemical formula: CaCO_3) designates a PCC product in the form of aggregates/agglomerates of individual PCC particles in which the aggregates/agglomerates have a surface area of at least $10 \text{ m}^2/\text{g}$ as determined by the BET method (Brunauer, Emmet, Teller, DIN 5 66131). The aggregates/agglomerates preferably have an equivalent spherical particle size (median particle size, MPS) in the range about $0.1\text{-}5.0 \mu\text{m}$, e.g. about $0.2\text{-}4 \mu\text{m}$, typically about $0.5\text{-}3.0 \mu\text{m}$, as determined e.g. by sedimentation on a Sedigraph 5100 from Micromeritics. The aggregates'/agglomerates' BET surface area will typically be up to about $100 \text{ m}^2/\text{g}$, more typically up to about $80 \text{ m}^2/\text{g}$, e.g. up to about $50 \text{ m}^2/\text{g}$, 10 e.g. up to about $30 \text{ m}^2/\text{g}$ and typically at least about $15 \text{ m}^2/\text{g}$, e.g. at least about $20 \text{ m}^2/\text{g}$. The aggregates/agglomerates consist of a greater or smaller number of single crystals having an equivalent spherical particle size of, typically, about $0.01\text{-}0.50 \mu\text{m}$.

It will be apparent to the skilled person that colloidal PCC can also occur as 15 aggregates with a surface area of less than $10 \text{ m}^2/\text{g}$, but as mentioned above the expression "colloidal PCC" in the context of the present application is to be understood as PCC with the stated surface area of at least $10 \text{ m}^2/\text{g}$. Correspondingly, according to the present invention a PCC mixture in which a part of the mixture is colloidal PCC with a surface area of at least $10 \text{ m}^2/\text{g}$ and a part of the mixture is "non- 20 colloidal PCC" can be used, "non-colloidal PCC" being defined as PCC with a surface area of less than $10 \text{ m}^2/\text{g}$.

An example of a colloidal PCC product according to the invention is given in the table below:

25

Parameter	Value
Median particle size, MPS (μm)	1.5
Brightness ($R_{457}\text{-ISO}$, %)	95.8
Surface area (BET, m^2/g)	25.0

The particle size distribution of this PCC product is shown in Fig. 1, whilst Fig. 2 shows a SEM picture of typical aggregates.

30 The colloidal PCC can, if desired, be used alone, i.e. as sole filler or pigment, in the manufacture of paper, but will presumably normally be used with at least one further

filler or pigment. These further fillers and pigments can be selected among both non-colloidal PCC and other types of fillers. There is a wide variety of types of PCC with different crystal forms which are suited as a filler, e.g. scalenohedral PCC, rhombohedral PCC, needle-shaped PCC (aragonite) and spherical PCC (vaterite).

- 5 Among other types of fillers and pigments which are suited for incorporation in paper, the following can be named: kaolin, calcined kaolin, talc, gypsum, ground marble, aluminium silicate, calcium silicate, magnesium silicate and other silicate-containing minerals, calcium sulphate, barium sulphate, titanium dioxide, zinc oxide, zinc carbonate, calcium sulfoaluminates (satin white), aluminium hydroxide, diatomaceous
- 10 earth, plastic particles and organic pigments. Paper manufactured according to the present invention can, in addition to the colloidal PCC, suitably contain one or more such PCC or non-PCC fillers or pigments to obtain the desired paper properties. Preferred further fillers are non-colloidal PCC, kaolin, calcined kaolin, talc, gypsum, chalk, ground marble, silicate-containing minerals and calcium sulfoaluminates. Non-
- 15 colloidal PCC, kaolin, calcined kaolin, chalk and ground marble are particularly preferred.

The finding which forms the basis of the invention, namely the fact that the porosity of paper can be regulated accurately by means of colloidal PCC, provides the

20 advantage, however, that the relative amount of the colloidal PCC relative to other fillers and/or pigments, as well as the colloidal PCC's properties (especially the surface area), can be adjusted in each individual case in order to achieve the properties which are desired for the paper in question. It is thus clear that the amount of colloidal PCC which is to be used depends on the type of paper to be manufactured and on the type

25 and amount of any other fillers. The amount of colloidal PCC to be used can therefore vary widely, i.e. from about 1% by weight of the total filler up to 100% of the total filler. The colloidal PCC will normally be used in an amount of at least 10% by weight, more typically at least 20% by weight, e.g. at least about 50% by weight, based on the weight of the total filler. The precise amount of colloidal PCC to be used in order

30 to achieve the desired properties for a given paper, including a particular porosity, will be easily determined by the skilled person, e.g. by simply preparing a series of paper samples in which there are used different amounts of the colloidal PCC relative to the other fillers.

Typically, the amount of colloidal PCC used according to the invention will be at least about 1 % by weight based on the total weight of the paper, more typically at least about 2% by weight, e.g. at least about 3% by weight, such as at least about 4% or 5% by weight. Depending on the total amount of filler in the paper and the proportion
5 of the filler that is comprised by the colloidal PCC, the colloidal PCC can of course be present in significantly higher amounts, however.

According to the invention, the colloidal PCC can be used as a filler to regulate the porosity and printing properties of any type of paper, including e.g. wood-containing
10 paper such as super-calendered (SC) paper/newsprint and wood-free paper such as fine paper. The invention is particularly suited for regulating the porosity and printing properties of uncoated paper, more particularly uncoated wood-containing paper, since these properties can be difficult to regulate in such paper compared to coated paper, where the porosity is controlled by the coating layer. In a preferred embodiment, the
15 invention relates to the use of the colloidal PCC in the preparation of SC paper.

It will be known to persons skilled in the art of paper manufacturing that the terms "wood-containing" and "wood-free" refer to whether or not the lignin component of the ligno-cellulose wood fibres has been removed. These terms are used herein in
20 accordance with their conventional meanings in the art, i.e. "wood-free" refers to cellulose fibres in which substantially all or at least most of the lignin has been removed, whereas "wood-containing" refers to ligno-cellulose fibres in which the lignin component has not been removed. While the specific amount of lignin that can be present in "wood-free" pulp may vary from country to country, this amount is
25 relatively small. For example, in Finland wood-free paper is defined as paper in which less than 10% by weight of the pulp is groundwood or other lignin-containing pulp. In the present context, "wood-containing paper" thus refers to paper in which the fibres comprise a substantial lignin component, wherein typically at least about 5% by weight of the pulp is lignin-containing pulp, more typically at least about 10% by
30 weight, such as at least about 15 or 20% by weight.

Removal of lignin to result in wood-free fibres can be performed by means of various well-known processes, e.g. using the Kraft process or by sulphite pulping. Such

processes that remove lignin from the wood fibres result in higher quality, but also more expensive fibres.

In the case of SC paper, in particular SC-A paper, containing colloidal PCC according to the invention, the porosity can e.g. be reduced to a value of at most about 0.30 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.28 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.26 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.24 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.22 $\mu\text{m}/\text{Pas}$. In other words, the porosity of the paper can be reduced to a value around, or possibly even lower than, the value of the porosity of an equivalent paper prepared on the basis of kaolin; this is illustrated in Example 1.

The present invention also allows improved porosity values in SC-B paper. Thus, SC-B paper containing colloidal PCC according to the invention may have a porosity of at most about 0.60 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.50 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.40 $\mu\text{m}/\text{Pas}$, e.g. at most about 0.35 $\mu\text{m}/\text{Pas}$.

It will be known to persons skilled in the art that SC paper may be classified into one of several subcategories based on properties of brightness, filler level, roughness, sheet gloss and porosity. The top grade of SC paper is thus SC-A+. SC-A paper typically differs from SC-A+ in having a somewhat lower brightness, while SC-B typically differs from SC-A in having one or more of a lower brightness, a lower filler level, a lower sheet gloss and a higher porosity.

In the context of the present specification and claims, the SC paper grades SC-A, SC-A+ and SC-B are defined as follows.

SC-A

Brightness $\geq 64\%$

Filler level $\geq 30\%$

Roughness (0.5 bar) $\leq 2.0 \mu\text{m}$

Roughness (1 bar) $\leq 1.5 \mu\text{m}$

Porosity $\leq 0.3 \mu\text{m}/\text{Pas}$

SC-A+

As SC-A above, but brightness $\geq 70\%$

SC-B

- 5 SC papers that do not fulfil the requirements for SC-A, but which fulfil the following requirements:

Brightness $\geq 60\%$

Filler level $\geq 15\%$

Roughness (0.5 bar) $\leq 3.0 \mu\text{m}$

- 10 Roughness (1 bar) $\leq 2.5 \mu\text{m}$

Porosity $\leq 0.6 \mu\text{m}/\text{Pas}$

- In the case of newsprint, the use of colloidal PCC according to the invention will make it possible to reduce the porosity of the paper to a value of at most about $20 \mu\text{m}/\text{Pas}$,
15 e.g. at most about $18 \mu\text{m}/\text{Pas}$, e.g. at most about $16 \mu\text{m}/\text{Pas}$; this is illustrated in Example 2. For SC paper, newsprint and other types of paper the porosity achieved in each case will depend among other things on the pulp used and on the amount and properties of the colloidal PCC and any other fillers used. The above mentioned porosity values for SC paper and newsprint, respectively, are therefore only to be
20 taken as examples, the important feature of the invention being the possibility of regulating (reducing) the porosity relative to the porosity which would otherwise be achievable in a given paper using a filler according to the prior art.

- Colloidal PCC can be prepared in a known manner by carbonating milk of lime (calcium
25 hydroxide slurry) under suitable conditions. The following conditions are to be regarded as a non-limiting example of the preparation of colloidal PCC:

- Burnt lime having a reactivity (DIN T_{50}) of between 10 sec. and 5 min. is slaked in
40°C warm water using a water/lime ratio of 4:1. The thus-prepared milk of lime is
30 diluted to 40% dry matter content, after which it is screened through a $500 \mu\text{m}$ screen.

After screening, the milk of lime is cooled to 20°C and carbonated in an appropriate gas flow reactor using flue gas or a CO₂-air mixture typically containing 20% CO₂. Carbonation is continued until the pH has fallen below 8.

- 5 At a gas flow of 2.5 m³ flue gas per m³ reactor volume the reaction will occur over a period of about 3 hours. After carbonation is completed the colloidal PCC is screened through a 45 µm screen.

The invention is further illustrated by the following non-limiting examples.

10

In the examples below, the following standards were used for determining paper properties:

Gram weight: Scan-P 6:75

- 15 Thickness: Scan-P 7:96

Density: Scan-P 7:96

Gloss: Tappi T480 om-92

Brightness: ISO 2470

Opacity: ISO 2471

- 20 Roughness: Scan-P 76:95

Porosity: PPS method

All amounts are by weight unless otherwise indicated.

25 EXAMPLE 1: REGULATION OF POROSITY IN SC PAPER

The following pigments were tested in SC paper:

	Kaolin reference Filler - M (ECC International)	Rhombohedral PCC Standard product (Faxo Paper Pigments A/S)	Colloidal PCC Experimental product (Faxo Paper Pigments A/S)
Brightness (R ₄₃₇ - ISO, %)	78.9	97.0	95.9
MPS (µm)	3.3	1.8	1.1
BET (m ² /g)	9.0	6.2	25

The test was carried out on a pilot paper machine with filler levels of 27, 30 and 33%.

- 5 The fibers were of Scandinavian origin and consisted of:

TMP (thermomechanical pulp) and GW (groundwood)	85%
Kraft (cellulose fibers processed by the "kraft" process)	15%

- 10 The following chemicals were used in the manufacturing process:

Retention agent none

Other none

pH adjusted to 7.3 by addition of H_3PO_4 .

15

For comparison purposes the results for paper are interpolated to 30% filler after calendering. The results are shown in the table below.

	Kaolin reference	Rhombohedral PCC	Colloidal PCC
Gram weight (g/m^2)	55	56	56
Thickness (μm)	49	54	55
Density (g/m^2)	1.123	1.030	1.020
Gloss (75° , %)	35	32	36
Brightness (R_{457} , ISO, %)	69.6	76.3	72.5
Opacity (%)	86.8	90.0	85.9
Roughness (μm)	1.48	1.48	1.46
Porosity $\mu m/Pas$	0.19	0.32	0.21

- 20 It can be seen from the above table that colloidal PCC surprisingly is capable of lowering the porosity of the paper from 0.32 $\mu m/Pas$ using a standard PCC to 0.21 $\mu m/Pas$ with colloidal PCC, which is on a par with the kaolin reference.

EXAMPLE 2: REDUCTION OF POROSITY OF NEWSPRINT USING COLLOIDAL PCC AS

25 FILLER

The following pigments were tested in newsprint:

	Reference Calcined Kaolin (Ansilex from Engelhard)	Faxe Chalk 89 Chalk (Faxe Kridt A/S)	Rhombohedral PCC (Faxe Paper Pigments A/S)	Colloidal PCC Experimental product (Faxe Paper Pigments A/S)
Brightness (R_{457} -ISO, %)	89.6	87.4	96.2	95.7
MPS (μm)	0.9	1.5	1.2	1.1
BET (m^2/g)	15.0	3.2	9.2	23.0

The test was carried out on a pilot paper machine with filler levels from 2-10%.

5 The fibres consisted of:

Unbleached TMP (thermomechanical pulp) 95%

Bleached cellulose prepared by the sulphate process. 5%

10 The following chemicals were used in the preparation:

Retention agent Percol 230L (cationic polyacrylamide from Allied Colloids)

Other none

pH adjusted to 7.3 by addition of H_2SO_4 .

15

For comparison purposes the results for paper are interpolated to 4% filler. The results are given in the following table, the gram weight of the papers being 46 g/m^2 .

	Reference Calcined Kaolin (Ansilex from Engelhard)	Faxe Chalk 89 Chalk (Faxe Kridt A/S)	Rhombohedral PCC (Faxe Paper Pigments A/S)	Colloidal PCC Experimental product (Faxe Paper Pigments A/S)
Thickness (μm)	106	106	105	105
Roughness (μm)	5.2	6.2	6.2	6.2
Porosity ($\mu\text{m}/\text{Pas}$)	17	21	20	15
Brightness (R_{457} -ISO, %)	63.5	61.1	61.6	60.5
Opacity (%)	90.2	89.4	89.8	90.6

It can be seen from the table above that colloidal PCC surprisingly is able to lower the porosity of the paper from 21 $\mu\text{m}/\text{Pas}$ with a standard PCC to 15 $\mu\text{m}/\text{Pas}$ with colloidal PCC, which is lower than the kaolin reference at 4% filler level.

5 Conclusion

By using colloidal PCC as filler the porosity of the paper is lowered significantly. The amount of colloidal PCC in the paper can thereby be varied as required, so that the porosity and thereby also the printing properties can be regulated precisely. The colloidal PCC can thus be used as required instead of or in combination with other conventional fillers and pigments in order to achieve the desired porosity.

EXAMPLE 3

A pigment mixture consisting of 50 parts (by weight) fine scalenohedral PCC, 30 parts fine rhombohedral PCC and 20 parts colloidal PCC was tested in production scale as a filler in SC-A grade paper at a commercial paper mill. The PCC pigment mixture was pH-stabilised by addition of a small amount of phosphoric acid in order to avoid the need for acid addition on the paper machine for pH-control. The properties of the PCC mixture and the reference clay filler used in the trial are listed in the table below.

	Reference kaolin clay (European filler grade)	Experimental PCC mixture (Faxo Paper Pigments A/S)
Brightness (R_{457} -ISO %)	79.2	94.1
MPS (μm)	1.38	1.62
BET surface area (m^2/g)	11.7	10.8

The pulp furnish composition was 50 parts deinked pulp (DIP), 40-45 parts groundwood (GW) and 5-10 parts Kraft pulp.

The trial PCC mixture was tested at a constant total filler level with two levels of PCC addition. The balance to give the total amount of filler is reference clay and filler introduced with the DIP (recycled paper).

The properties of the papers resulting from the trial are listed in the table below.

	Reference	Trial 1	Trial 2
Added PCC ¹	0 %	10 %	20 %
Added clay ¹	32 %	22 %	12 %
Analysed CaCO ₃ content ¹	1.5 %	13.4 %	24.2 %
Analysed clay content ¹	37.6 %	25.6 %	15.2 %
Gram weight	57 g/m ²	56 g/m ²	56 g/m ²
Roughness TS (0.5 bar)	1.70 μ m	1.75 μ m	1.65 μ m
Roughness WS (0.5 bar)	1.70 μ m	1.70 μ m	1.55 μ m
Porosity (PPS) ²	0.122 μ m/Pa.s	0.197 μ m/Pa.s	0.228 μ m/Pa.s
Gloss 75°, TS MD	50 %	45 %	45 %
Gloss 75°, WS MD	48 %	49 %	49 %
Brightness R ₄₅₇ -ISO	66.4 %	70.1 %	72.1 %
Opacity	92.1 %	92.5 %	91.8 %

1) By weight, based on the total weight of paper; TS = topside; WS = wireside; MD = machine direction

2) PPS = Parker-Print-Surf method

5

The runnability of the paper machine remained good during the two-day trial period and it was possible to increase the production capacity by 1.5%. The Hydrocol™ two-component retention system was used on the paper machine. The amount of cationic polymer could be reduced during the trial as the PCC pigment mixture was easier to retain than the reference clay. The pH in the paper machine headbox was 7.4 prior to the trial and it increased only slightly (to 7.6) during the trial.

The paper produced during the trial showed excellent results in full-scale commercial printing. It is remarkable that the paper brightness has been increased by 6 percentage points without any loss in opacity. The resulting 72% brightness is close to the superior SC-A+ quality.

EXAMPLE 4

20 A pigment mixture consisting of 80 parts (by weight) fine rhombohedral PCC and 20 parts colloidal PCC was tested in production scale as a filler in SC-B grade paper at a commercial paper mill. The rhombohedral PCC and the colloid PCC had BET surface areas of approximately 7 and 20 m²/g, respectively, to provide a mixture having an overall BET surface area of 9.1 m²/g as indicated below. The PCC pigment mixture

was pH-stabilised by addition of a small amount of phosphoric acid in order to avoid the need for acid addition on the paper machine for pH-control. The properties of the PCC mixture and the reference fillers used in the trial are listed in the table below.

Filler:	Reference kaolin clay (European filler grade)	Reference PCC	Experimental PCC mixture (Faxo Paper Pigments A/S)
Brightness (R_{457} -ISO %)	76.6	96.2	95.4
MPS (μm)	2.13	1.70	1.31
BET (m^2/g)	11.9	8.6	9.1

5

The pulp furnish composition was 30-35 parts deinked pulp (DIP), 10-15 parts chemothermomechanical pulp (CTMP) and groundwood (GW), adding up to a total of 100 parts.

- 10 The trial PCC mixture was tested at a constant total filler level with two levels of PCC addition. The balance to give the total amount of filler is reference clay and filler introduced with the DIP (recycled paper).

The properties of the papers resulting from the trial are listed in the table below.

15

	Reference	Trial 1	Trial 2
Added Faxo PCC ¹	0 %	11 %	18 %
Added reference PCC ¹	11 %	0 %	0 %
Added clay ¹	11 %	11 %	4 %
Analysed CaCO_3 content ¹	15.8 %	14.8 %	22.4 %
Analysed clay content ¹	17.8 %	17.4 %	11.2 %
Gram weight	57 g/m^2	56 g/m^2	56 g/m^2
Roughness TS (0.5 bar)	2.80 μm	2.90 μm	2.90 μm
Roughness WS (0.5 bar)	2.60 μm	2.80 μm	2.80 μm
Porosity (PPS)	0.570 $\mu\text{m}/\text{Pa}\cdot\text{s}$	0.514 $\mu\text{m}/\text{Pa}\cdot\text{s}$	0.554 $\mu\text{m}/\text{Pa}\cdot\text{s}$
Gloss 75°, TS MD	27 %	27 %	26 %
Gloss 75°, WS MD	24 %	25 %	24 %
Brightness R_{457} -ISO	63.4 %	62.6 %	64.8 %
Opacity	96.4 %	95.9 %	96.0 %

1) By weight, based on the total weight of paper: TS = topside; WS = wireside; MD = machine direction.

The runnability of the paper machine remained good during the two-day trial period and it was possible to increase the production capacity by 1.3%. The Hydrocol™ two-component retention system was used on the paper machine. The amount of cationic polymer could be reduced during the trial, as the PCC pigment mixture was easier to retain than the reference clay. The amount of blue and yellow colour could be reduced as well. The pH in the paper machine headbox was 7.3 prior to the trial and it was stable at 7.2 ± 0.1 during the trial.

The paper produced during the trial showed excellent results in full-scale commercial printing. The pulp bleaching was reduced in order to keep the paper brightness within the production specifications. The reduced amount of bleaching chemicals is an advantageous cost saving for the paper mill and environmentally beneficial.

EXAMPLE 5

A pigment mixture consisting of 80 parts (by weight) fine rhombohedral PCC and 20 parts colloidal PCC was tested in production scale as a filler in SC-A grade paper at a commercial paper mill. The PCC pigment mixture was pH-stabilised by addition of a small amount of phosphoric acid in order to avoid the need for acid addition on the paper machine for pH-control. The properties of the PCC mixture and the reference clay fillers used in the trial are listed in the table below. The paper mill alternates between use of two clays in their normal production.

Filler:	Reference kaolin clay (European filler grade)	Experimental PCC mixture (Faxo Paper Pigments A/S)
Brightness (R_{457} -ISO %)	80.7	94.1
MPS (μm)	1.79	1.62
BET (m^2/g)	15.4	10.8

The pulp furnish composition was 75 parts deinked pulp (DIP), 20 parts groundwood (GW) and 5 parts Kraft pulp.

The trial PCC mixture was tested at a constant total filler level with all fresh filler added being PCC. The balance to give the total amount of filler is filler introduced with the DIP (recycled paper). Paper was made in three gram weights: 48, 52 and 56 g/m². For the sake of simplicity only results for 56 g/m² are shown. The results at the other 5 gram weights were similar.

The properties of the papers resulting from the trial are listed in the table below.

	Reference	Trial
Added PCC ¹	0 %	17 %
Analysed CaCO ₃ content ¹	3.5 %	18.3 %
Analysed clay content ¹	32.9 %	17.4 %
Gram weight	57 g/m ²	57 g/m ²
Roughness TS (0.5 bar)	2.4 µm	2.20 µm
Roughness WS (0.5 bar)	2.65 µm	2.55 µm
Porosity (PPS)	0.252 µm/Pa.s	0.367 µm/Pa.s
Gloss 75°, TS MD	32.9 %	31.7 %
Gloss 75°, WS MD	26.1 %	29.2 %
Brightness R ₄₅₇ -ISO	66.0 %	66.4 %
Opacity	94.1 %	95.6 %

1) By weight based on the total weight of paper; TS = topside; WS = wireside; MD = machine direction.

The runnability of the paper machine remained good during the two-day trial period and it was possible to increase the production capacity by 1.2%. The Hydrocol™ two component retention system was used on the paper machine. The amount of cationic polymer could be reduced by approx. 20% during the trial as the PCC pigment mixture was easier retained than the reference clay. The pH in the paper machine headbox was 7.6 prior to the trial and it increased only slightly (to 7.7) during the trial.

The paper produced during the trial showed excellent results in full-scale commercial printing. It is remarkable that the paper mill had to totally stop bleaching their DIP in order to keep the brightness within the production specifications. This is a big economic advantage and also environmentally beneficial.

EXAMPLE 6

A number of fillers and filler mixtures were tested in a dynamic sheet former trial.

The fillers were three PCCs from Faxe Paper Pigments A/S, Denmark (a fine rhombohedral PCC, a fine scalenohedral PCC, and a colloidal PCC), and a kaolin clay from Dorfner. The properties of the fillers used in the trial are listed in the table below.

Filler	Brightness (R_{457} -ISO %)	MPS (μm)	BET (m^2/g)
Fine rhombohedral PCC	94.6	0.90	7.9
Fine scalenohedral PCC	95.7	2.13	9.3
Colloidal PCC	95.4	1.40	28.1
Kaolin clay (Dorfner)	81.7	2.02	8.4

5

Handsheets were made on a dynamic sheet former from Fibertech AB. The pulp furnish consisted of 50 parts groundwood, 30 parts DIP and 20 parts Kraft pulp. The target filler level was 35% by weight of the total weight of the paper. The results are listed below. The target gram weight of the handsheets was 56 g/m^2 (The actual gram weights varied between 53.2 and 58.1 g/m^2). Handsheets were made at three target filler levels, which were 30%, 33% and 36% filler by weight based on the total weight of the paper. The paper quality parameters were interpolated to a 35% filler level and the results are listed below.

10

Trial No:	1	2	3	4	5	6	7
Fine rhombohedral PCC ¹	100	80	70	50			
Fine scalenohedral PCC ¹					100	80	50
Colloidal PCC ¹		20	30	50		20	
Kaolin Clay ¹							50
Analysed CaCO_3 content ² (%)	32.5	32.9	32.3	32.7	32.9	32.8	18.8
Analysed clay content ² (%)	2.5	2.1	2.7	2.3	2.1	2.2	16.2
Gram weight (g/m^2)	54.2	53.9	55.0	56.1	57.0	56.5	56.9
Roughness TS (1 bar) (μm)	1.33	1.35	1.31	1.35	1.28	1.28	1.16
Porosity (PPS) ($\mu\text{m}/\text{Pa}\cdot\text{s}$)	0.276	0.271	0.265	0.252	0.337	0.259	0.236
Gloss 75°, TS MD (%)	32.0	35.1	37.2	40.1	39.7	40.2	46.7
Brightness R_{457} -ISO (%)	70.2	69.5	66.6	67.6	68.8	67.4	66.6
Opacity (%)	92.7	93.0	93.8	92.9	93.5	92.9	92.7

15 1) parts by weight, 2) By weight based on the total weight of paper; TS = topside; WS = wireside; MD = machine direction.

CLAIMS

1. A process for regulating the porosity and printing properties of uncoated paper, the process comprising using a sufficient quantity of colloidal PCC having a BET surface
5 area of 10-100 m²/g as a filler to achieve a desired porosity of the paper.
2. A process according to claim 1, wherein the paper is wood-containing paper.
3. A process according to claim 2, wherein the paper is SC paper, in particular SC-A
10 paper, and wherein colloidal PCC is used in a quantity sufficient to achieve a porosity of at most 0.30 µm/Pas, e.g. at most 0.28 µm/Pas, e.g. at most 0.26 µm/Pas. e.g. at most 0.24 µm/Pas, e.g. at most 0.22 µm/Pas.
4. A process according to claim 2, wherein the paper is SC-B paper, and wherein
15 colloidal PCC is used in a quantity sufficient to achieve a porosity of at most 0.60 µm/Pas, e.g. at most 0.50 µm/Pas, e.g. at most 0.40 µm/Pas, e.g. at most 0.35 µm/Pas.
5. A process according to claim 2, wherein the paper is newsprint, and wherein
20 colloidal PCC is used in an amount sufficient to achieve a porosity of at most 20 µm/Pas, e.g. at most 18 µm/Pas, e.g. at most 16 µm/Pas.
6. A process according to any of the preceding claims, wherein the colloidal PCC has
25 a BET surface area of 15-50 m²/g.
7. A process according to claim 6, wherein the colloidal PCC has a BET surface area of 20-30 m²/g.
8. A process according to any of the preceding claims, wherein colloidal PCC is
30 incorporated into the paper in an amount of at least about 1% by weight based on the total weight of the paper.
9. A process according to claim 8, wherein colloidal PCC is incorporated into the paper in an amount of at least about 2% by weight based on the total weight of the paper.

10. Paper containing colloidal PCC having a BET surface area of 10-100 m²/g as a filler.

- 5 11. Paper according to claim 10, comprising at least one further filler selected from non-colloidal PCC, kaolin, calcined kaolin, gypsum, chalk, ground marble, silicate-containing minerals, sulphate-containing minerals, oxide-containing minerals, carbonate-containing minerals, hydroxide-containing minerals, calcium sulfoaluminates, plastic particles and organic pigments.

10

12. Paper according to claim 10 or 11, wherein the colloidal PCC has a BET surface area of 15-50 m²/g, e.g. 20-30 m²/g.

13. Paper according to any of claims 10-12, said paper being uncoated.

15

14. Paper according to any of claims 10-13, wherein the colloid PCC is present in an amount of at least about 1% by weight, e.g. at least about 2% by weight, based on the total weight of the paper.

- 20 15. Uncoated wood-containing paper containing colloidal PCC.

16. SC paper containing colloidal PCC and having a porosity of at most 0.30 µm/Pas, e.g. at most 0.28 µm/Pas, e.g. at most 0.26 µm/Pas, e.g. at most 0.24 µm/Pas, e.g. at most 0.22 µm/Pas.

25

17. SC paper according to claim 16, wherein the paper is SC-A paper.

18. SC-B paper containing colloidal PCC and having a porosity of at most 0.60 µm/Pas, e.g. at most 0.50 µm/Pas, e.g. at most 0.40 µm/Pas, e.g. at most 0.35 µm/Pas.

30

19. Newsprint containing colloidal PCC and having a porosity of at most 20 µm/Pas, e.g. at most 18 µm/Pas, e.g. at most 16 µm/Pas.

20. Paper according to any of claims 15-19, comprising at least one further filler selected from non-colloidal PCC, kaolin, calcined kaolin, gypsum, chalk, ground marble, silicate-containing minerals, sulphate-containing minerals, oxide-containing minerals, carbonate-containing minerals, hydroxide-containing minerals, calcium sulfoaluminates, plastic particles and organic pigments.
21. Paper according to any of claims 15-20; wherein the colloidal PCC has a BET surface area of 10-100 m²/g, e.g. 15-50 m²/g, e.g. 20-30 m²/g.
22. A pigment mixture suitable for paper manufacture and comprising colloidal PCC having a BET surface area of 10-100 m²/g in combination with at least one filler selected from the following pigments: kaolin, calcined kaolin, gypsum, chalk, ground marble, silicate-containing minerals, sulphate-containing minerals, oxide-containing minerals, carbonate-containing minerals, hydroxide-containing minerals, calcium sulfoaluminates, plastic particles and organic pigments.
23. A pigment mixture suitable for paper manufacture and comprising a combination of colloidal PCC having a BET surface area of 10-100 m²/g and non-colloidal PCC.
24. A pigment mixture according to claim 22 or 23, wherein the colloidal PCC has a BET surface area of 15-50 m²/g, e.g. 20-30 m²/g.
25. A pigment mixture according to any of claims 22-24, wherein the colloidal PCC comprises aggregates/agglomerates having an equivalent spherical particle size in the range 0.1-5.0 µm, e.g. 0.2-4 µm, typically 0.5-3.0 µm, wherein the aggregates/agglomerates consist of single crystals having an equivalent spherical particle size of about 0.01-0.50 µm.

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☒ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.